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THE RELATION OF BIOLOGY TO PHYSICS[1]

IT came to me as a great surprise that a biologist should be invited to give an address at the dedication of a physical laboratory. I realized my unworthiness to represent the many sides of biology on such a significant occasion, but I dared not decline on these grounds, because there are certain things that I want to say, and your invitation gives me a chance to say them.

First of all, I should like to point out that one of the most important developments in recent times is the recognition of the need in the biological sciences of workers trained in physics. It seems to me that the reverse is also true—that a biologist is needed in physical laboratories. Perhaps to-day is the first time that this has been recognized, and Vassar has been foremost to recognize this fact, even though the biologist is allowed to remain for only one short hour.

When we dedicate a new building to *biology* at Columbia I shall see to it that one of your physicists is invited to respond to the sentiment, "the relation of physics to biology." As there is no immediate prospect of this building there will be several years to think it over.

If the president of Vassar or the program committee or whoever arranged these dedication exercises had intended that the speaker to-day should analyze the relation of *physiology* to physics, he or they, I am sure, would have picked out a physiologist. The physiologist would have had an easy and even a delightful time, for physiology has long since been wedded both to physics and to chemistry. A modern physiological laboratory is scarcely to be distinguished from a physical laboratory, having borrowed its instruments, at least, from the former.

There is, however, another side of biology that is conspicuous by its absence from most physiological laboratories. The traditional physiology of the schools is interested in the functioning of the organs. It takes the *organism* for granted and tries to find out how its organs work in health and in disease. The close relation of functional physiology to medicine explains and justifies this limitation of its field of interests.

[1] One of a series of addresses given at the inauguration of the new physical laboratory at Vassar College in October, 1926.

But there is another physiology, one that is concerned with the coming into existence of those organs whose function the physiologist studies. This coming into existence may have taken place in the past (we call it, then, evolution), or it may relate to the development of each individual each time it comes from an egg.

Now evolution has been largely treated as a historical question, one which in the last fifty years zoologists, botanists and paleontologists have studied from various angles.

But what reason is there to suppose that evolution really came to an end with the appearance of man on the earth? Is evolution not going on at the present time; and if so, is it not more open to investigation than in the past? The answer is, I think, that there is every probability that evolution is still going on as merrily as ever, and that man himself is not the finished product of evolution that he likes to believe.

It is, however, the other field of research relating to the creative process that is open to most direct attack. It may have taken millions of years for the present fauna and flora to have developed; it may take only a few days for an egg to develop into an organism. The millions of years that it took to evolve the kinds of individuals living to-day seem to have been condensed into a few hours. We can see taking place before our very eyes every single change in the development of an egg. What is not visible we can make visible with our stains and microtomes.

Now it had been supposed, for a hundred years, that we could interpret embryonic development as a historical series of events, condensing an eternity into a day. We know better now. At the time when the phylogenetic interpretation of embryology was in full swing, and before it became generally admitted that we could not hope by this means to discover how the egg develops into an organism—at that time a new school arose which directed attention to the need of a physical and chemical, *i.e.*, a causal interpretation of the underlying changes that take place during embryonic development. Its advocates called the new movement "developmental mechanics."

Unfortunately, William Roux, who is generally recognized as the foremost advocate of the new method, dealt largely in causal philosophical discussions of the supposed principles of developmental mechanics. Roux himself was primarily an anatomist and not a physiologist. The single pioneer experiment of note that he made consisted in killing one of the first two cells of the dividing egg of the frog. The other living cell produced a half-embryo. From this slender basis of fact Roux built up an elaborate theory of development. Driesch, on the basis of other observations, discovered that when the first two cells of the dividing egg of the sea urchin and ctenophor are separated, each develops in one case into a whole embryo, and in the other case into a half-embryo. From these and other observations that consisted mainly in isolating different parts of the egg Driesch elaborated another theory of development that was ultra-physical. He tried to show that back of the physical and chemical changes that take place during development there must be present a guiding principle, a *vis essentialis*, which he identified as the Aristotelian entelechy. Driesch's interesting speculations reached a wide audience, in part because of the brilliant logic by which he supported his views, and, in part, because an appeal to mysticism has in itself a fascination for the human mind untrained in scientific methods.

All this is past history, and little more than an episode in the process of biological thought. There was, in fact, a quick reaction from the stagnation that was the immediate outcome of this attempt to remove the problem of development from the field of physics to that of philosophy. From then onwards a study of development from a chemico-physical standpoint began, and forged steadily ahead until to-day the pack is in full cry.

The most immediate result of this new work was to reveal how completely ignorant we were of the constitution of living materials, and eggs in particular. It was obvious that we didn't really know what we were talking about, and that the problems of development are complex and need to be unraveled patiently, one by one, before we can hope to have the faintest idea of what is taking place.

This has led to two results. We realize how futile it is to attempt to make up grand philosophies of development, and we realize that only through an exact knowledge of the chemical and physical changes taking place in development can we hope to raise the study of development to the level of an exact science. In a word, we realize that we need all the help that physics and chemistry can give if we are ever to pass beyond the transcendental point of view that dominated the earlier work. Biologists have come, as I have said, to realize that there are problems in development to be found at every turn, which the physicist and the chemist confess they are not yet able to handle. In part this is due, I think, to their unfamiliarity at first hand with the problems themselves, because they did not realize that organic matter presented such problems. That is one of the reasons why I said a little while ago that biologists were needed in physical laboratories.

I should like to illustrate the need of physical knowledge in biological work by a few very simple

examples which, in a general way, are familiar to you, yet will serve, I hope, to bring home the need for the cooperation for which I am pleading.

The egg is a cell, and the first step in development is taken when the egg divides into two parts. Cell-division is one of the most general phenomena of living things. The first indication of division in a living egg is a constriction that appears on the surface, which gradually spreads and encircles the egg. It cuts into the interior until two hemispheres result that flatten against each other. After a pause of less than an hour, a new division appears at right angles to the first, dividing the material into quadrants.

This process continues until a thousand or more cells may be produced before any of the embryonic organs are laid down. Our microscopes reveal, even in a transparent egg, only a small part of what is happening inside the egg. By means of an elaborate technique the interior changes have been made out. This technique consists in staining the substances of the egg in various stages of division. The exploration of the interior is further carried out by cutting the egg into hundreds of thin slices—as many as five thousand to an inch. Such sections show in the middle of the egg an inner sphere, or nucleus. The walls of the nucleus dissolve just before division is to take place, and a number of tiny rods or chromosomes reveal themselves. There is a characteristic number of these for each species of animal or plant. Moreover, they often differ in shape and size. Whenever differences are present we find that there are two chromosomes of each size or shape.

The next step is the appearance of a spindle-shaped figure near the chromosomes. Into the middle of the spindle the chromosomes move, or are carried, and there they arrange themselves in an equatorial plate.

Even before this time we discover a clear line running through the length of each chromosome. Each has split throughout its length and two daughter halves are present.

Each half of each chromosome then moves to one pole and its sister half to the opposite pole.

It is about this time that the constriction appears on the surface of the egg. As it deepens it cuts through the middle of the spindle separating the daughter chromosome groups from each other.

Around each group of chromosomes a fluid accumulates, and the chromosomes begin to lose their staining property. Suitable stains reveal that each chromosome becomes branched and the branches have the appearance of forming a network in the new nucleus that is now formed.

A resting stage of about half an hour follows, and then the same process repeats itself—the nucleus wall in each cell disappears, the chromosomes reappear, a spindle develops, the chromosomes again split lengthwise into daughter halves.

I have given the briefest outline of the process of cell-division that is described in every text-book of biology. What does it all mean? What, to begin with, causes the constriction to appear on the egg at the moment when the chromosomes have already divided and separated? The division of the cell impresses us as a simple physical phenomenon. Many attempts have been made to account for it, but none are satisfactory, because, I think, we do not know as yet enough of the physical constitution of the materials of the egg to permit more than provisional guesses.

This, however, is only the first problem that presents itself! What makes each chromosome split lengthwise? The chromosomes are too deeply imbedded in the egg for us to invoke external agents. It must seem that some sort of a molecular event is taking place, whose nature is entirely unknown to us, and yet, who will doubt that it, too, may be a very simple physical process.

How do the chromosomes reach the equator of the spindle? What moves the daughter halves to opposite poles? When they reach the poles why do they undergo a reverse series of changes and pass once more into a resting stage? What are they doing while resting? Probably each is growing to its original size, but what is the nature of this growth? Here we meet with a dozen questions, all calling aloud for answers. It seems that no one but a physicist can hope to solve them.

There is another important question connected with the chromosomes for which we have no answer: I refer to the union or conjugation of the chromosomes that takes place once, and once only, in the cycle of the life of each individual organism.

When the germ-cells, that is, the egg-cells and the sperm cells, after having passed through many ordinary divisions (such as I have just described), reach their final stage of maturity a strange thing happens. Although the chromosomes have remained apart through a long series of cell-divisions, now they come together in pairs.

The two members of each pair approach each other and come to lie side by side. It looks as though they had fused and reduced the visible number of chromosomes to half the original number. But we have many reasons for thinking that they do not fuse but only lie closely apposed.

There is another fact connected with this union of like-chromosomes that was at first wrongly interpreted: one member of each pair has come from the father of the individual, the other from the mother.

It was supposed, wrongly as I have said, that the conjugation of the chromosomes had something to do with their origin—in a word, that they mated because one had come from a male, the other a female.

Now we know that this is not the cause of their union, but that they mate because they are like each other—in fact they may be identical. Here is a fine opportunity for metaphysical discussion, but I like to think rather that the event is purely physical, even although I must confess that we do not know what kind of an attraction draws like-chromosomes together, and not even if it is an attraction.

I want again to emphasize that these chromosomes have been living together, literally, for months or even for years and have shown no tendency to come together. Then suddenly they all forget, as it were, their repugnances, and become attracted to each other, but only within strict class limits, for no chromosome makes the mistake of uniting with a wrong one.

Having gone so far, you will permit me to go one stage further and consider briefly some further information that we now have concerning the intimate constitution of the chromosomes themselves.

This evidence has come from a study of genetics. It carries us far beyond anything that even the highest powers of our microscope reveal. I can not attempt to discuss the sources of this evidence, or to weigh the value of the method by which the conclusions are reached. But the result is so simple that there is no difficulty in presenting the conclusions without the arguments for or against them.

The evidence from heredity, then, has revealed that each chromosome is made up of a chain of discrete particles which we call genes—because they are, as it were, the basis of the genealogy of every individual.

There are probably thousands of these genes in every chromosome, and no two genes appear to be alike. Each individual animal or plant is the product of the activity of all these genes, and heredity is the result of the shuffling of these genes in each generation.

In several plants and animals we can refer these genes to particular chromosomes, and in one animal at least about four hundred genes have been placed. On the assumption of their relative positions with respect to one another, we can predict what the numerical results will be in inheritance for some four hundred different characters. The theory justifies itself in that it allows one to predict the outcome in terms of numbers for all these four hundred characters whose genes have been located.

If there were time, I should like to go much further and give an account of the chromosomes in relation to their constituent elements, but I can add only one further point, namely, that the genes divide when the chromosomes divide, and collectively their division is what we see when each chromosomal rod splits throughout its length. It is the genes that come together during the conjugation of the chromosomes. They must come together with extraordinary precision, which implies probably that we are dealing with events of a molecular order. We can go no further until physics has furnished us with a key to unlock these extraordinary events.

One other example I should like to cite: one of the most successful attempts to apply the methods of physics to a biological problem of fundamental significance. The turning of plants and animals towards, or away from, the light has been found to obey the laws of a physical reaction known as the Bunsen-Roscoe law. This law states that a given amount of radiant energy produces a definite photochemical effect provided the product of the intensity of the light and the time of its action remain constant. That is to say: the same end is reached with a high intensity and a short exposure as with a low intensity and a long exposure.

The particular mechanism by means of which the reaction or orientation is carried out is a matter of secondary interest, for the movements may be carried out by the six legs of an insect, the four legs of a vertebrate, the body wall muscles of a worm, the cilia of a protozoon, or by differential growth on the opposite sides of a plant. The details of the machinery are of biological interest, of course, but the discovery that the reaction that sets them in motion obeys a simple law of physics is of the greatest significance, for it brings with it the hope that we may discover the kind of physical phenomena that lie at the bottom of the orienting reactions of living things.

Perhaps it has occurred to you that I have for a moment wandered away from my immediate subject, for tropisms furnish an example of a purely functional response. They belong to functional physiology rather than to development. This is true. The organism that responds is already there, it is given; the reaction is as perfect the first time it is formed as at any later time. This holds to a high degree in all those reactions that we classify as instincts. When the machine is finished, that is, when it has developed, the response is automatic. Until the last bolt is put in there is no reaction. When the bolt is in place the machine is then ready to perform perfectly the specific movements which it is designed to carry out. This simplifies the functional problem immeasurably.

But biologists are familiar with another set of reactions in animals, in which the whole or large parts of the nervous system and sense organs are involved, that are concerned with a kind of development phe-

nomenon. These types of reactions characterize especially the vertebrates, although they are by no means exclusively confined to them. I refer to the formation of "associations." Here we find the coming-into-being of new things, or conditioned reflexes, or whatever name we may choose to give to the phenomena. What we want to discover is the physical nature of the nervous material that makes possible the building up of such complex types of substitutions and combinations on which the life of each individual may come to depend. We are ourselves, we suspect, largely creatures of our associations and conditioned reflexes that are formed and reformed every day of our lives, but moulded, and set perhaps, at an incredibly early age. We call it training, or education, or ethics—we have many names for the process—but the background of it all is not understood. Here perhaps is a new physics—a whole new world, from which biologists so far have been excluded because, I suspect, the purely physical aspects of the reaction system are unknown. Whether the nature of the association process will be revealed in a physiological or in a physical laboratory remains to be found out. In order to study it our best chance will be to put some physicists in the biological laboratory, and some biologists in the physical laboratory. Meanwhile, we shall have to get along with the kind of arguments that philosophy, metaphysics and introspective psychology have supplied.

Even the wonderful work that the physiologist Pavlow has done by applying objective quantitative methods to the study of associations takes the material basis—the nervous system—as given.

Two opposing and apparently irreconcilable movements have been going on for years in the biological sciences, that relate to the living and the dead. The most courageous leaders of one school assert boldly that there is a fundamental difference between biology and physics; the more timid speak of an irreducible minimum of living phenomena that is not explicable on physical principles and then magnify this minimum into some sort of principle. It would carry us far into the realm of philosophy to attempt to follow out the fine-spun dialectic and logic that has been used in the discussion of these speculations. To-day we are concerned with more practical and less abstruse questions; but there is undoubtedly something at stake here that concerns physics and biology. It involves the method of science.

We speak loosely of experimental science. What is this science? Does it apply only to the physical sciences, astronomy, physics and chemistry, or does it apply equally to the biological sciences? I need not dwell on the absurd idea that to reduce life to physics is crass materialism. This way of condemning all attempts to apply the method of the physical sciences to the phenomena of life is so transparent that it is seldom resorted to any longer. For what is less materialistic to-day than the most advanced views of physicists themselves concerning what used to be called matter, meaning a stone or a brick?

Among the illuminati, however, the objection has shifted to a more refined comparison. The physical world is mechanistic; the biological something more. What the "moreness" is depends on the metaphysical system that each philosopher has up his sleeve.

All this need not detain us, but may be left to the realm of the higher dialectics; for in these comparisons I am trying to make we are not concerned with absolutes and finalities, but with the more prosaic endeavor to discover if possible whether, and in what sense, it is worthwhile to carry on the biological sciences by the application of the methods that experience has taught to be profitable in the physical sciences—profitable in the broadest use of the term. What, in a word, has given to physics her recognized leadership in science? Fortunately there is a pretty general consensus of opinion on this score. Physics has progressed because, in the first place, she accepted the uniformity of nature; because, in the next place, she early discovered the value of exact measurements; because, in the third place, she concentrated her attention on the regularities that underlie the complexities of phenomena as they appear to us; and lastly, and not least significant, because she emphasized the importance of the experimental method of research. An ideal or crucial experiment is a study of an event, controlled so as to give a definite and measurable answer to a question—*an answer in terms of specific theoretical ideas,* or better still an answer in terms of better understood relations. This sounds, I fear, somewhat pompous. Let me give a more concrete illustration. If I set a house on fire I am not performing an experiment. I am simply acting foolishly; but I can employ heat to advantage in a different way. If I study the rate of a chemical reaction at different temperatures, I may discover some relation between the rate of change at different temperatures and be able to deduce, from an inspection of the measurements, certain constant relations between heat and the rate of reaction. I may find that, within a certain range, at least, a definite relation holds. By extending the experiment to other substances I may find the same relation to hold between different temperatures, and feel safe then in predicting for other unknown substances that the same correlation will hold. Surprising as it may seem, this has been found to be true not only for physical events but for those in the biological field. It is the dis-

covery of constants such as these in the biological field that assures us that the method of physical science is applicable to living matter.

Why, then, should anyone hesitate to apply the method of physics to the living world? Living things, as we know, contain no chemical elements that are not found in the inorganic world. They depend for their very existence on an interchange of material with the outside world. The law of the conservation of energy applies to an animal or man as much as to a piece of coal. If we went no further than this, might it not be worth while to find out all we can in the way of method from physics and chemistry and see what they will give us and not indulge in ultra-physical speculations in our present state of ignorance about the simplest conditions relative to living things?

It may be conceded, at once, that in the organic world the conditions are more complex than those with which the physicist has to deal. It is much more difficult to make real experiments that reveal constants, although comparatively easy to set the house afire. Yet a beginning has been made and the success has been as great as was to be looked for. There are, however, two questions of importance concerning the methods of biology that are so significant and fraught with so much danger for the future of experiment in biology that they can not be safely ignored. I refer first to the rôle of mechanism or arrangement in the functional as well as in the developmental phenomena of living organisms; and second, to the disparagement of all attempts to find uniform constants in the reactions and behavior of living things.

My good friend Jennings has, in a recent address at the opening of the Whitman laboratory of experimental zoology at the University of Chicago, stressed one side of the question. I am in close agreement with much that he has to say in the admirable presentation of the method of experimental science as applicable to biology, but there are certain implications in his discussion with which I do not find myself in complete sympathy. Since these questions are intimately bound up with my topic to-day, I should like to devote a few minutes to their discussion.

Jennings points out that something more is needed in the study of living things than a knowledge of the environment and a knowledge of the chemical constitution and physical conditions of the substances that make up the organism. This something-more is its structure, both gross and minute, which is sometimes vaguely spoken of as its organization. Jennings says that, "in the days before experimentation, zoologists had given a romantic and mystical turn to the phenomena of structure in organism; they built upon it a great edifice which was called morphology; they discovered in organic structure plans, styles comparable to the diverse styles of architecture, to Gothic, Romanesque, Classical, and the rest. But the physiologist said: This may be pretty, but is it science? It is not! Out with it!! We shall have nothing to do with morphology—it is fantastical. And, throwing away the baby with the bath water, they largely rejected also the rôle of structural arrangements, even in experimentation."

Now, all this is a very entertaining account of what happened to morphology, but the picture is overdrawn, and in my opinion not quite fair to physiologists in particular. For while it is true that the student of functional physiology paid scant attention to the evolutionary speculations of morphologists, they can not be said to have neglected the organization of the animals and plants on which they experimented—not only as to their gross structure, but as to the microscopic structure of the cells and tissues also. Recall, for example, the attention that physiologists have given to the structure of the heart as a pumping organ and to the distribution of the blood vessels, even down to the capillaries. Recall again how closely the physiology of the nervous system and sense organs kept in touch with the morphology and minute structure of the brain, nerves and organs of sensory perception. Physiologists accepted these structures as they found them and kept close to their arrangements. It is true, as I have already said, that physiologists have paid little attention to the problem of development, or the coming into existence of the more visible organs and functions during development. They left these problems to the embryologists who, for a long time, were under the lethal influence of the doctrine that "ontogeny repeats phylogeny." But at last a few physiologists did wake up to the situation and began to apply physiological methods to embryological development. They scandalized embryologists by assuming that the egg was little more than a bag of jelly. They spoke in terms of chemistry and physics and quantitative methods but made wide guesses as to the kind of jelly they were dealing with. They often showed an appalling lack of concern as to the visible changes in the egg. They were willing, despite their boasted quantitative method, to call an embryo anything and everything that swam 'round in their finger bowls. It is, I think, neglect of this kind of information that Jennings must have in mind when he says they threw the baby out with the bath.

But even before all this went on, embryologists too had seen the futility of the phylogenetic interpretations and turned their attention to the study of the changes that take place in the egg when it begins to differentiate its regional parts, and they had discovered that, far from being a bag of jelly impinged

upon by a salt solution, extensive rearrangements of materials take place that are correlated with the important developments that follow. All this may not be physiology, as yet, but no one who is familiar with the literature of that period will doubt that it is essential to know something about these intrinsic movements if an adequate basis for an understanding of the essential problems of development is ever to be gained. I stand therefore with Jennings if this is what he means when he says that a knowledge of structure is important for the study of development. But when this is agreed to, it still seems to me that we have done little more than prepare the ground for a real physical and chemical study of development, for the essential questions still remain. What, for instance, causes the redistributions of the materials of the egg? It does not suffice to know that a new distribution is present. What we need to find out is how this redistribution brings in its train the local differences that take place. I fail to see how further and further accumulations of this sort can ever lead us beyond a pure description of what takes place in each kind of egg. For these reasons I am not sure that I can follow Jennings when he goes on to say, that "it is to this decisive rôle of diverse arrangements that are due the seemingly anarchistic principles which we deduced from the early experiences of experimenters. To it is due the fact that one can not directly transfer the experimental results that we have gotten in one field to another field. . . . To this is due the maxim that 'what one organism can't do, another can.' To this is due the deceptiveness of the method of crucial experiment so much employed—the single experiment that is to give a generally valid answer to the question proposed."

There are two implications in this statement that may very easily be misleading. In the "early experiences" referred to there were no scientific "principles" at all deduced. A few facts were added and much speculation. It is the *absence* of principles that makes it impossible to transfer the "results" from one field to another. In the second place, there were no "crucial experiments" carried out at all—if this term means what physicists mean when they use it.

Let me quote what Poincaré said not a few years ago. "We all know that there are good experiments and poor ones. The latter will accumulate in vain; though one may have made a hundred or a thousand, a single piece of work by a true master, by a Pasteur, for example, will suffice to tumble them into oblivion. Bacon would have well understood this; it is he who invented the phrase *Experimentum crucis*."

Now, I can not go further into a discussion of these questions. But while I agree with Jennings most heartily that, in the study of organisms, we can not neglect a single detail of their structure, our real problem is not to discover how many kinds of structures exist, but whether there are common principles that run through them all. If there are no such principles, then we are indeed headed towards chaos. We have not gone very far in our analyses it is true, but far enough, I think, to encourage us to go on. Take, for example, cell-division in all its diversity: are we to go on studying the variations resulting from slight differences in structure between the eggs of every species; or is it not better to attempt to discover whether there are not relatively few simple physical *principles* involved in cell-division. If so, then the differences depending on the details of structure may take care of themselves.

There is another question raised by Jennings which, as stated by him, may be easily misunderstood in its implications, although I am confident that Jennings would in general readily agree with much that follows. Jennings cites as typical of scientific method the progress of modern genetics. "At first," he says, "there are laws of inheritance, abstract and mathematical; they hang in the air. These laws as they are followed become more varied, more arbitrary, more unintelligible. And thus it is found that their form and content is the resultant of the operation of special arrangements of the organic material—certain systems of structure of the chromosomes. Where these arrangements are different the rules of heredity are different. These rules become intelligible only through understanding these arrangements and their operation."

Any one not familiar at first hand with the history of genetics since 1900 might be led to suppose from Jennings' statements that Mendel's laws had been abrogated by the extension that took place as the subject progressed. In fact, however, Mendel's conclusions stand to-day exactly as Mendel stated them. They at least have certainly not become "more arbitrary, more unintelligible." Mendel pointed out that the numerical results that he obtained in his crosses with peas could be explained by two simple hypotheses that we may call the law of segregation and the law of independent assortment. The first law has been found to have wide application. It is the fundamental principle on which all later discoveries rest. It is a broad generalization based on numerical data and allows us to predict with accuracy the outcome of a given situation.

It is true that during the last twenty-six years there has been some progress in the study of genetics. We have found, for instance, that Mendel's second law applies only within certain limits that can be accurately stated, but his two laws still hold for the cases that Mendel studied and for the characters of the

majority of animals and plants so far studied. But because linkage and crossing-over have been added to our equipment, and because with knowledge of these we can apply the laws of heredity over a much wider field, is this a reason for stating that because "the systems of structure are different the rules of heredity are different"? It is quite true that the information concerning the arrangement of the elements of heredity has helped us enormously to a fuller understanding of other types of heredity than those that Mendel first discovered, but of course Jennings does not mean to say that this wider knowledge made Mendel's laws more unintelligible, although a casual reader might interpret him in this way.

On the contrary, Mendel, by great insight in interpreting the results of experiments that were carefully and deliberately planned to determine how individual characters are inherited, arrived at two generalizations that are fundamental for all later work. His method was one that a physicist might have been proud of, and without his discoveries I think we might still be floundering around, as had the earlier hybridists, because they did not understand how to ask an intelligent question in order to get an intelligent answer. For it is not every experiment, so called, that will give the answer sought. Nature is sometimes as oracular as the priestess of Delphi. It took even physics a long time to find out how to question nature intelligently. In finding this out it was slowly discovered that certain methods of approach were more satisfactory than others. I have indicated what those methods are, and I think that we biologists can not do better than to borrow them from the physical sciences.

THOMAS H. MORGAN

COLUMBIA UNIVERSITY

SOLAR RECORDS IN TREE GROWTH[1]

THE freedom from undergrowth of the pine trees of northern Arizona and their exposure to the characteristic droughts of the country first suggested to the writer the idea that their variations in growth had a climatic and solar origin. Accordingly a long search was made for evidence of such relationship, which has resulted in the identification, dating and measurement of several hundred thousand rings in something under a thousand trees scattered widely about this and other countries. Many interesting results have been obtained and an extensive technique of ring-study has been developed. Of that technique the most important line has been the study of cycles which might have a solar cause.

It is no surprise that variations in climate can be read in the growth rings of trees, for the tree ring itself is a climatic product. In the spring the pines put on a rapid growth of soft white tissue, which continues till lack of moisture, through temperature or dryness, diminishes the growth and stimulates the tree to prepare for winter by putting on a red lignite ring. The growth gradually stops and in sufficiently dry or cold weather comes to an end till the warmth and moisture of spring revive it.

If successive years were exactly alike, the rings would all be of the same size with some alteration with age or injury. But successive years are not alike, and in that difference some factors appeal strongly to the trees. In northern Arizona, with its limited moisture and great freedom from pests and with no dense vegetable population, this controlling factor is identified as rainfall. So it is not astonishing that the pine trees, as tested near Prescott, Arizona, show a correlation with rainfall between 80 per cent. and 85 per cent.

The extent of the dependence of this southwestern rainfall on solar changes is still a point under discussion. Helmann found the sunspot cycle in the rainfall of North Germany, and it has been identified in many places, most notably perhaps in the well-known thirty-five-year Brückner cycle. But the strongest bit of evidence of solar effect on climate is in the trees themselves, for in this region where the trees are specially sensitive to rainfall they show the eleven-year sunspot cycle in a striking manner, and they show it in a double-crested curve just as the rainfall itself in southern California shows it. This has been brought out recently in a dramatic manner. From the start the sunspot cycle was sought in the Arizona pines, and during long parts of their growth it seemed perfectly evident, yet for scores of years it failed, and in 1914 I very nearly gave up the idea that the trees really show it, because near 1700 it failed entirely. Finally in 1919 (Carnegie Publication 289) I gave the facts about it, saying that from 1660 to 1720 the sunspot curve "flattens out in a striking manner," and again, "the sequoias show strikingly the flattening of the curve from 1670 or 1680 to 1727." Early in 1922 I received a letter from Professor E. W. Maunder, of England, calling attention to the prolonged dearth of sunspots between 1645 and 1715 and saying that if there were a connection between solar activity and the weather and tree growth, this extended minimum should show in the weather and in the trees. On receipt of the letter this period was immediately recognized as the interval referred to in which there was entire failure in attempting to trace

[1] Address of the retiring vice-president of Section D—Astronomy—American Association for the Advancement of Science, Philadelphia, December 29, 1926.

solar effects. A more recent review of the eleven-year period in those trees confirms its well-marked existence from before 1400 to the middle of the seventeenth century. Soon after 1700 it reappears, but not in complete form until the latter part of that century.

The test was then carried to the sequoias. It was found that the slow-growing sensitive upland trees were the ones which best displayed the solar cycle, and also that the interference by other cycles was such that the double period of about twenty-three years was a more satisfactory manner of tracing the changes of the solar period. When these conditions were allowed for, the same result was obtained as before from Arizona.

In 1922 or before, it was noticed that when the eleven-year cycle disappeared from the trees near 1700, two other cycles, one of ten or twenty years and the other of fourteen or twenty-eight years, became prominent in its place in the Arizona pines. Soon after it was noticed that the Vermont hemlocks show the same change at that time, and so also the sequoias of California. And then it was observed that these three basic cycles appear generally in the western trees; these are, first, eleven and one half or twenty-three years; second, ten or twenty years; and, third, fourteen or twenty-eight years. And these three cycles were recently confirmed in a study of 52,000 measures of rings in 305 trees scattered over ten western mountain states. And there is reason to think that all these cycles come from the sun, for at different times the sunspot cycle itself has changed to one or the other of them. For example, from 1748 to 1788 there were four complete cycles of ten years each; from 1788 to 1830, forty-two years, there were three complete cycles of about fourteen years each. It seems at least likely that these other two cycles, found in western trees with extraordinary persistence, are also of solar origin.

In the recent extensive study of cycles in the western yellow pine, it was noted that the moist coastal regions show the eleven-year cycle more generally than the drier interior sections or the Rocky Mountain area. This agrees with the result of ten years ago in which the wet-climate Scotch pines of North Europe, especially near the Baltic Sea, showed a direct single-crested sunspot cycle having a remarkable resemblance to the curve of sunspot numbers. Their growth gave the solar changes with an accuracy exceeding that of any trees of the southwestern area. Recent study confirms the further statement that this is a wet-climate phenomenon. But it is not yet clear just what causes this accuracy of record in the wet-climate trees. It seems probable that the wet-climate trees follow the sunspot cycle more closely than do the weather elements in which they live, and it is perhaps safe to repeat the suggestion made by the writer in 1922 that there may be some more direct line of cause and effect from the sun to these trees than we have taken into account, such, for example, as radiation (possibly of short wave length), that is especially favorable to trees growing generally under cloudy skies. In tree groups along the Atlantic coast of this continent, the eleven-year cycle is also prominent, but it has a phase displacement of two or three years.

The pages above give the probable forms which solar records take in tree growth. It was expected by the time of this writing to have a fairly complete historic study of solar variations, but the formal work along that line has had to be postponed for a time. In a general way it is safe to say that the sunspot cycle and its double and triple value are very general. The double value has persisted in Arizona for five hundred years and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Brückner's cycle, has operated in Arizona for the last two hundred years and in Norway for four hundred at least. A hundred-year cycle is very prominent throughout the three thousand years of sequoia record and also in the five hundred years of yellow pine. It is still uncertain whether the eleven-year cycle can be judged by the variations in its double value, which, from the absences of certain interfering periods, is more easily traced through long periods. But a very incomplete review of the sequoia record suggests that from 1300 B. C. to well after 1000 B. C. the eleven-year cycle was well developed; then it slowly decreased. From 300 B. C. on it was increasing and was very conspicuous during the first two centuries of our era. Then it decreased and from 400 to 650 A. D. was only occasionally evident. From 650 to 850 or 900 it seems fairly continuous. Then it appears only occasionally until about 1250, when it again becomes fairly continuous, except for the changes in the seventeenth century above noted.

Such then are the solar records so far translated from tree growth, whose complete understanding, it is believed, will give us extensive historical information of this sort in many different parts of the world.

A. E. DOUGLASS

FLAGSTAFF, ARIZONA

THE SIGNIFICANCE AND SCOPE OF THE IDEA OF FREQUENCY IN PHYSICS[1]

IT has long been recognized that exponential (periodic) solutions of certain partial differential equations are essentially necessary when such equa-

[1] Paper presented at the Philadelphia meeting of the American Physical Society.

tions are applied to bounded systems, whereas the use of periodic solutions of such equations (of the familiar wave equation, for example) for extended media is largely a matter of convenience. We do, as a matter of fact, have periodic or quasi-periodic waves in extended media so that to this extent the use of periodic solutions of the wave equations in extended media is justifiable; and the important phenomena of interference and diffraction and the phenomena of dispersion settle to steady states, which are observable and amenable to calculation, only for steadily maintained periodic waves or for an utterly disordered but steadily maintained wave-aggregate like white light.

That we do have periodic or quasi-periodic waves is due to the periodic or quasi-periodic character of the disturbance in the bounded and nearly closed system or systems in which the waves originate. *Periodicity seems always to be associated with the motion of bounded and nearly closed systems.* Aside from translatory motion, the steady state motion of a bounded system must be singly or multiply periodic. Water waves seem to be the only exception to the general rule that periodicity or quasi-periodicity always originates in a bounded system. Water waves are formed by the wind, a wind of a certain velocity tends to produce waves of a certain velocity and therefore of a certain wave-length and frequency because the velocity of water waves is a function of the wave-length.

The wide-spread notion that wave motion is essentially periodic is wholly erroneous; the general solution of the simple wave equation

$$\frac{d^2y}{dt^2} = v^2 \frac{d^2y}{dx^2}$$

is wholly devoid of the element of periodicity.

Before the advent of the Bohr theory it was quite generally recognized that periodicity was a very restricted thing, as explained above, and that complete periodicity, which is always assumed in the treatment of interference and diffraction, was an ideal, not a fact; but the Bohr relation $W = h\nu$ raised the idea of frequency to an exalted position which puzzled us all, and the Bohr theory was leading us all to the acceptance of frequency as one of the most fundamental of unitary (non-resolvable) ideas of physics! Indeed, we do have very much more sharply defined frequencies in light than in any other branch of physics; a pendulum may vibrate a hundred times before its amplitude is greatly reduced, but the electron in a hydrogen atom would, according to classical electrodynamics, make an enormous number of revolutions before its energy would be greatly reduced.

There had come to be an excessive emphasis on the notion of frequency before the advent of the Bohr theory, excessive because it was non-critical, and the Bohr theory brought in the idea of frequency in a way that made a critical examination of the idea impossible; the idea of frequency as it appears in the Bohr theory must be accepted as an "absolute" or not at all, and to the critical student of physics there is no such thing as an "absolute."

The excessive (non-critical) emphasis on the notion of frequency before the advent of the Bohr theory can be seen in nearly every treatise on wave motion. Many years ago I came upon the following: "To prove that a phenomenon is due to wave motion it is sufficient to show, first, that it is periodic and, second, that it is propagated at a finite velocity"—instantly the Gatling gun came into my mind; the effect of the Gatling gun is periodic and it travels at a finite velocity! Periodicity is not an essential property of wave motion; and every one who is familiar with the terms wave-velocity and group-velocity and especially every one who understands, with Heaviside, that wave motion when not too highly idealized always partakes more or less of the characteristics of diffusion, knows that wave motion is not necessarily characterized by a velocity!

In connection with our statement that periodicity of waves always originates in a bounded and nearly closed system (usually the emitting system but possibly the reacting receiving system; thus the sharply defined frequencies of the various parts of the spectrum of white light are properly assignable to the action of the prism, they do not exist as such in the light before it passes through the prism) it is of interest to recall Helmholtz's comments on the question of the physical justification of the resolution of a periodic sound into Fourier components. Helmholtz says that the Fourier resolution is justified because of the sharply defined maximum of response of a harmonically oscillatory receiver when the frequency of the free oscillations of the receiver coincides with the frequency of any one of the Fourier components of the impinging sound.

I am most decidedly inclined towards the highly restricted idea of frequency of the pre-Bohr days and it pleases me greatly to observe that the new "wave mechanics" of Schrödinger is bringing us back to the older point of view. The Schrödinger mechanics is based on a generalized wave equation, and Schrödinger limits himself to exponential (periodic) solutions because he is primarily interested in the motion of bounded and nearly closed systems such as electrons, and atoms, and molecules. Thus the idea of frequency in the new "wave mechanics" is

exactly on a par with the idea of frequency which existed in the pre-Bohr days.

Perhaps the boldest step which has been made in the development of the new "wave-mechanics" is de Broglie's quantization of the total energy (including mass energy) of the electron. It is allowable, perhaps, to think of the electron as a bounded system, and as a very nearly closed system. If the energy of the electron is to be thought of as due to motion within the electron, this motion must be periodic because a steady state of motion in a bounded system (except for purely translatory motion) must be periodic. Of course the motion might involve a number of distinct periods, as in the transverse vibration of a steel bar, for example, but one's first guess would be one frequency ν and therefore the total energy of the electron would be placed equal to $h\nu$.

The quantization of the motion of a bounded closed system seems to me to be more reasonable than the quantization of a detached portion of light energy whose frequency *was* fixed by the system which emitted the light.

WM. S. FRANKLIN

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

SCIENTIFIC EVENTS

THE NEW HARVARD COLLEGE OBSERVATORY IN SOUTH AFRICA

A CONTRACT has been let by the Harvard College Observatory for the construction of a 60-inch reflecting telescope to be mounted at a new southern astronomical station to be located somewhere in the Union of South Africa. The exact site has not yet been chosen, but a location near Bloemfontein, capital of the Orange Free State, is being seriously considered.

The new telescope, to be the largest in the southern hemisphere, will be constructed by J. W. Fecker, at Pittsburgh, Pennsylvania. It will have an aperture of a little over 60 inches and a focal length of 27 feet. It will be used for photographic, photometric and spectrographic work on stars and nebulae, and for study of the Magellanic clouds and the large southern clusters.

Two photographic refractors and three photographic telescopes, now at the Boyden station at Arequipa, Peru, will be moved to the new site in South Africa where they will be placed on mountings now being made in this country.

The transfer of the station from Peru to South Africa is being supervised by Dr. John S. Paraskevopoulos, superintendent of the Arequipa station. The new station is expected to be the largest in the southern hemisphere. Photographs will be shipped regularly to the Harvard Observatory at Cambridge for study and filing in the photographic collection there.

The new telescope has been made possible by gifts to the Harvard Observatory by the Rockefeller International Education Board and by Harvard University.

A MEDICAL CENTER FOR WASHINGTON, D. C.

PLANS for the establishment in Washington of an extensive medical center have been launched by the executive heads of the Garfield Memorial Hospital, the George Washington University and the Washington Home for Foundlings.

The basis of the agreement is the fact that the experience of many other cities has demonstrated the value of the establishment of great medical centers in which close and lasting associations have been formed between the work of theoretical medical instruction and the practical instruction afforded by the facilities for clinical teaching found in hospitals and dispensaries.

The plan contemplates that the Washington Home for Foundlings shall build upon the grounds of the Garfield Memorial Hospital a hospital for the care and treatment of cancer and cancer research laboratories, under the provisions of the Warwick bequest. This building will be known as "The Helen L. and Mary E. Warwick Memorial."

The George Washington University Medical School will erect a new medical school building in the vicinity of Garfield Memorial Hospital. Ultimately the work now being done in the George Washington University Hospital will be transferred to the Garfield Memorial Hospital, but the work of the George Washington University Hospital will be maintained until, in the judgment of the trustees of the university, it is practicable to sell the hospital and medical school property upon favorable terms and conditions.

Upon discontinuance of the university hospital, the university medical faculty and hospital staffs will be organized in a manner to carry on the clinical and laboratory work in the Garfield Hospital and the Cancer Hospital under conditions most favorable to high grade hospital service and medical education as well.

Those who are parties to the agreement wish to emphasize the fact that there will be no change in the activity of any of the institutions until such time as the actual changes in buildings are brought about, and that the support given to the various institutions will be continued with the added incentive that all will now be contributing to an important project along the most efficient and modern lines.

LOWELL LECTURES BY PROFESSOR A. V. HILL

THE series of Lowell lectures to be delivered in Boston by Dr. A. V. Hill, Foulerton research professor of physiology in the University of London, will begin on March 7. They will continue throughout the month on Mondays and Thursdays at five o'clock in the afternoon, in accordance with the following synopsis:

March 7—Physiology as a meeting-ground of the sciences. The different branches of science are mutually dependent upon one another. Physiology in a very special degree is so dependent. It may be regarded as an application of the methods and the results of all the other sciences to the study of the phenomena of life.

March 10—Mechanism and purpose. Three chief factors emerge from the study of life phenomena: (a) the complexity, beauty and sufficiency of the mechanisms by which results are brought about, and the certainty that all these have a material basis; (b) the extraordinary adaptation of means to an end and the existence of an apparent "purpose" in the mechanisms employed; (c) the arbitrary and freakish paths along which living creatures have passed in evolution. To recognize these factors is a task for science; to reconcile them, at present a task for philosophy.

March 14—Nerves and their messages. The living strands along which messages pass in the animal carry "waves of electrochemical change." The nature of these waves, the means by which they are started, and some of the results of studying them.

March 17—Muscles and how they move. A muscle is a mass of contractile jelly-like threads. Much is known about muscles, chiefly because they work so long and so well after removal from the body. Work, fatigue and recovery in the isolated muscle. Strength and speed of muscular response.

March 21—The heart and the involuntary muscles. Voluntary and involuntary muscles. The heart and its labors.

March 24—The supply of oxygen, fuel and energy to the muscles. Muscles, like all machines, require oxygen, fuel and energy. The rôle of the lungs and circulation in supplying them with these. The measurement of the energy liberated and of the fuel burnt in the body.

March 28—The cooperation of nerves and muscles. Most postures or movements are automatic or reflex, depending on the play or interplay of muscular response, with ingoing and outgoing nervous impulses. The accuracy and quickness of such automatic action. The synthesis of voluntary movement.

March 31—Speed, strength and endurance. The factors which limit speed of movement; the wastefulness of high speeds. "Optimum" speed. Skill, strength, endurance, and the factors on which these depend. The quantitative assay of muscular effort and deductions therefrom.

CHIEF OF THE U. S. BUREAU OF CHEMISTRY AND SOILS

THE United States Civil Service Commission states that the position of chief of the Bureau of Chemistry and Soils of the Department of Agriculture is vacant, and that, in view of the importance of the position in the whole field of chemical and soil research, and to insure the appointment of a thoroughly qualified man for the work, an unusual method of competition will be followed to fill the vacancy.

Instead of the usual form of civil service examination, the qualifications of candidates will be passed upon by a special board of examiners, composed of Dr. A. F. Woods, director of research in the Department of Agriculture, Dr. Joseph G. Lipman, director of the New Jersey Agricultural Experiment Station, and Mr. Frederick W. Brown, consulting examiner of the United States Civil Service Commission. For the purposes of this examination, these men will be examiners of the Civil Service Commission.

The examination will consist solely of a consideration of qualifications by this special board. The minimum qualifications for consideration are a doctor's degree from a college or university of recognized standing, at least ten years' experience in the direction and performance of chemical and soil research of a character to show the required degree of knowledge and ability in both chemistry and soils, administrative capacity of the highest order, and thorough familiarity with the literature of chemistry and soils, and with the activities of scientific and professional organizations and associations concerned with the subjects of chemistry and soils. The applicant must also have a personality which will enable him to deal tactfully with the personnel of the research units to be under his direction, and to enter into successful cooperative relations with other research and administrative agencies.

The duties of the position are to direct and administer the work of the Bureau of Chemistry and Soils carried on by a personnel of approximately 540 persons under an annual appropriation amounting to $1,115,005 for the fiscal year 1928; and personally in cooperation with assistant chiefs and the respective division leaders to initiate, outline, develop and direct the various phases of research, demonstration and service work devolving upon the bureau, under the agricultural appropriation and other acts, and by the direction of the secretary of agriculture.

The entrance salary for this position is $6,000 a year. Promotion may be made without change in assignment up to $7,500 a year.

Qualified persons who wish to be considered for this vacancy should apply to the United States Civil Service Commission, Washington, D. C., for Form 2600,

which must be executed and returned, with a list of the applicant's technical publications and reprints of such of these publications as are available, in time to be on file in the office of the Civil Service Commission at Washington not later than April 5, 1927.

MEMORIAL MEETING FOR DR. CHARLES D. WALCOTT

AT the memorial meeting for the late Dr. Charles D. Walcott, secretary of the Smithsonian Institution, held in the auditorium of the National Museum on February 10, the following resolutions were presented by the committee named by Acting Secretary Abbot, consisting of Dr. George P. Merrill, *chairman*, Dr. J. Walter Fewkes, Mr. James G. Traylor, and Mr. Webster P. True:

We of the Smithsonian Institution, its several branches and coordinate scientific institutions of Washington, have assembled here to-day to do honor to one of our number who achieved in scientific circles an exalted position attained by few. During the twenty years that Dr. Walcott so eminently served as secretary of the Smithsonian Institution; during the forty or more years of his life in Washington, he displayed to a degree that excited our greatest admiration a capacity for the dual duties of research and administration. Under his administration the institution has passed successfully through a trying period and is but now emerging upon what he firmly believed will prove the most useful and striking period of its existence. Meanwhile, in his studies of the geology and paleontology of the older rocks of the earth's crust he won world-wide recognition among scientific men and became the recipient of nearly every honor that can be bestowed, both in America and abroad. It is not necessary that his achievements and successes be dwelt upon in detail. He has gone from us.

Be it therefore resolved, that we here express our personal sense of loss in the death of a friend and leader who, through his unfailing courtesy and encouragement in our various lines of work, aroused our deepest respect and admiration. In the passing of Secretary Walcott the institution which he loved and served so well has suffered a severe blow and his friends and associates have lost an inspiring leader.

Be it also resolved, that we, Dr. Walcott's associates, extend to his family our deepest sympathy in their bereavement.

A number of Dr. Walcott's associates present at the meeting expressed their esteem and affection for him, and their admiration for his scientific work. Among these were Dr. Keith, Mr. Newell, Dr. David White, Dr. Abbot, Dr. Wetmore, Dr. Bassler and Mr. Victory.

SCIENTIFIC NOTES AND NEWS

PROFESSOR JAMES KENDALL, professor of chemistry in the Washington Square College of New York University, has been elected a fellow of the Royal Society.

DR. F. G. BANTING, professor of medical research in the University of Toronto, has been awarded the Cameron prize in recognition of his investigations on insulin and on the treatment of diabetes. This prize, which was founded in 1878, "may be awarded annually to a person who, in the course of the five years immediately preceding, has made a highly important and valuable addition to practical therapeutics."

DR. SIMON FLEXNER, director of the Rockefeller Institute for Medical Research, has been elected a member of the German Academy of Natural Sciences (Leopoldina) in Halle, Germany.

DR. JOHN M. T. FINNEY, professor of surgery, the Johns Hopkins University Medical School, Baltimore, who gave the annual Hunterian lecture in London, has been made an honorary fellow of the Hunterian Association and also of the Medical Society of London.

DR. AMEDEE GRANGER, professor of radiology in the graduate school of medicine at Tulane University, was awarded a gold medal by the Radiological Society of North America at its annual convention held in Milwaukee for his work on the sphenoid sinus.

THE Collingwood prize of the American Society of Civil Engineers has been awarded to Cecil Vivian von Abo, of Johannesburg, South Africa, for his paper on "Secondary Stresses in Bridges."

DR. ROBERT BARANY, professor of medicine at the University of Upsala, has received from the King of Sweden the Commander-Cross of the Order of the North Star.

SIR SIDNEY HARMER will retire, under the age clause, on March 9 from the directorship of the Natural History Museum, South Kensington, London.

THE seventieth birthday of Professor D. A. Low, emeritus professor of engineering at the University of London, was celebrated on February 9 by a dinner arranged by his old students.

DR. ALEXANDER ZIWET, professor emeritus of mathematics in the Engineering College at the University of Michigan, was honored recently by fellow members of the Apostles' Club on the occasion of his seventy-fourth birthday.

IN response to an invitation from the American Association for the Advancement of Science, the following have been appointed by their respective organizations to constitute a committee to promote research in American colleges: Vernon Kellogg, for the National Research Council; Charles R. Mann, for

the American Council on Education; Edward C. Armstrong, Princeton University, for the American Council of Learned Societies; Knight Dunlap, the Johns Hopkins University, for the Social Science Research Council, and Maynard M. Metcalf, the Johns Hopkins University, for the American Association for the Advancement of Science.

PROFESSOR HUGH S. TAYLOR, chairman of the department of chemistry at Princeton University, has been elected chairman of the central petroleum committee of the National Research Council. The duties of this committee are the allocation of fellowships for fundamental studies in petroleum, in cooperation with the American Petroleum Institute.

AT the Philadelphia meeting of the Society for the Promotion of Engineering Education, Dean O. M. Leland, of the University of Minnesota, was elected president.

PROFESSOR A. F. ROGERS, of Stanford University, was elected president of the Mineralogical Society of America at the meeting held during the Christmas holidays at Madison, Wis.

DR. CARL J. WIGGERS, professor of physiology and Dr. Howard T. Karsner, professor of pathology, at Western Reserve University, were among those elected fellows of the American College of Physicians at the recent meeting in Cleveland.

DR. D. H. LINDER was recently appointed mycologist at the Missouri Botanical Garden, to fill the vacancy caused by the retirement of Dr. Edward A. Burt. Later Dr. Linder had the opportunity of joining an expedition to Africa under the auspices of the Harvard School of Tropical Medicine and was granted leave of absence for a year. Dr. L. O. Overholts, professor of botany at Pennsylvania State College, on leave of absence from that institution, was appointed mycologist for the year 1926–27.

THE U. S. Department of Commerce has announced the appointment of Frederick L. Washbourne, of New York City, to take charge of the organic chemical section of the Division of Chemistry, and Edmund C. Wood, also of New York City, to succeed George N. Priest in charge of the paint and naval stores section of the division.

DR. H. L. VAN VOLKENBERG, formerly connected with the U. S. D. A. Bureau of Biological Survey and the U. S. Bureau of Fisheries, has been appointed associate parasitologist at the Porto Rico Experiment Station.

E. W. GUERNSEY recently severed his connection with the Fixed Nitrogen Research Laboratory at Washington, and is now with the research department of the Consolidated Gas, Electric Light and Power Company, Baltimore.

PROFESSOR C. T. BRUES, of the Bussey Institution, Harvard University, spent the early part of the winter at the Harvard Tropical Laboratory at Soledad, Cuba, investigating the insect fauna of the region. He was accompanied by Mrs. Brues, who made studies of the local grass flora.

DR. W. J. SPILLMAN, economist of the division of farm management and costs, U. S. Bureau of Agricultural Economics, left Washington on February 1 for the Lapwai Indian Agency in Idaho to begin a study of the agricultural problems of the Indians of the country for the Institute of Government Research, Washington, D. C.

WHILE abroad on leave during the present semester, Professor R. J. Roark, of the college of engineering at the University of Wisconsin, will study new methods of testing materials at the University of London, England.

DR. M. A. BARBER and Mr. W. Komp, of the U. S. Public Health Service, returned on February 2 to the Malaria Research Laboratory at Greenwood, Miss., after a malaria survey of 7,000 emigrants from Haiti to Cuba.

DR. IVAN PARLAPANOFF, chemist of the public health service of Bulgaria, is in the United States under the auspices of the Rockefeller Foundation and is spending some time in the food control and microchemical laboratories of the Bureau of Chemistry in Washington, studying the organization of food and drug control work in this country.

DR. FRITZ PANETH, professor of inorganic chemistry at the University of Berlin and non-resident lecturer at Cornell University during the first semester of the 1926–1927 academic year, is making a lecture tour of the East and Middle West, speaking in fifteen cities. His itinerary includes Rochester, Buffalo, Cleveland, Toledo, Detroit, Ann Arbor, Chicago, Madison, Minneapolis, Urbana, Washington, New York, Boston and New Haven. Professor Paneth addressed the scientific staff of the Rockefeller Institute for Medical Research on February 25 on "Radio Elements as Indicators."

DR. EDGAR L. COLLIS, professor of preventive medicine, University of Wales, Cardiff, Wales, will deliver a Hanna lecture on March 7 at the Medical Library Auditorium, Cleveland, on "Modern Industrialism and Its Effect on Distribution of Population." Dr. Collis will also deliver the fifth Harvey Society lecture, at the New York Academy of Medicine, on Saturday evening, March 19, at 8:30. His subject will be "Phthisis and Industrialism—Silicosis."

DR. DOUGLAS W. JOHNSON, professor of physiography in Columbia University, will give four lectures on the Richard B. Westbrook free lectureship at the Wagner Free Institute of Science, New York, on March 4, 5, 11 and 12. Dr. Johnson's subject will be "An Interpretation of Atlantic Coast Scenery."

DR. B. S. HOPKINS, professor of chemistry at the University of Illinois, addressed a public meeting held at the University of Pittsburgh under the auspices of the Sigma Xi Alumni Association on February 19. The address was preceded by an informal dinner to Dr. Hopkins.

DR. ELLIOTT C. CUTLER, professor of surgery in the school of medicine of Western Reserve University, delivered the McArthur Lecture of the Billings foundation before the Chicago Institute of Medicine on February 25, speaking on "Post-operative Abscess of the Lung."

DR. CHRISTINE LADD-FRANKLIN gave a lecture on "The Color Sensations" at Columbia University on February 18. She also exhibited her new collection of color-charts made by Ahmend at The Hague.

DR. GEORGE GRANT MACCURDY, of Yale University, director of the American School of Prehistoric Research, lectured before the Wyoming Historical and Geological Society of Wilkes-Barre, Pa., on February 4, his subject being "The Evolution and Character of Paleolithic Art."

ON February 16 Dr. Louis Kahlenberg, professor of chemistry at the University of Wisconsin, lectured at Notre Dame University, South Bend, Ind., "On the Separation of Crystalloids from one another by Dialysis." On the following day he addressed the chemists at Purdue University on the subject "New Contributions to the Chemistry of the Keratins."

ON February 12, Professor H. A. McTaggart, of the department of physics, in the University of Toronto, delivered an address to the Royal Canadian Institute, on the subject "The Measurement of Color." On February 19, D. Jenness, chief of the division of anthropology at the National Museum of Canada, Ottawa, delivered an address to the institute on the subject "Who are the Indians?"

SIR ERNEST RUTHERFORD gave the twelfth Guthrie lecture to the Physical Society of London on February 25, taking as his subject "Atomic Nuclei and their Transformations."

PROFESSOR HENRY E. ARMSTRONG will deliver the Horace Brown Memorial lecture of the Institute of Brewing in the lecture theater of the Institution of Electrical Engineers, London, on February 25. The Horace Brown Medal will be presented to Professor Armstrong during the course of the evening.

FREE public lectures have recently been given at the University of London as follows: "Allergic Diseases caused by Factors of Climate," by Professor W. Storm van Leeuwen, University of Leyden, on February 14, 15 and 16; "The Ostracoderms, their Organization and Relationships," by Professor E. A. Stensio, of the Royal State Museum of Natural History, Stockholm, on February 17, 18, 22 and 24.

DR. ROBERT WELLES FISHER, formerly professor of materia medica and pharmacology, University of Utah School of Medicine, died on January 16, aged sixty-four years.

THE death is announced of Dr. Hermann von Tappeiner, professor of pharmacology in the University of Munich, aged eighty years.

PROFESSOR C. GAGEL, formerly director of the Museum of the Prussian Geological Survey at Berlin, has died, aged sixty-two years.

PROFESSOR MARIO BEZZI, who was recently appointed professor of zoology in the Royal University of Turin, died on January 14.

THE American Institute of Chemists held its annual meeting in the Sterling chemistry laboratory at Yale University, under the presidency of Professor Treat B. Johnson, professor of organic chemistry at Yale University. The meeting included an evening session open to the public, at which Secretary of Agriculture W. H. Jardine spoke, and over which President James Rowland Angell, of Yale, presided. The scientific meeting was held from 2:00 to 5:00 P. M. in the large lecture hall of the Sterling chemistry laboratory. The program included a symposium on "Chemists' Contracts," which dealt primarily with the rights of the chemist and the manufacturer to discoveries made by the chemist while in the manufacturer's employ. The evening meeting was held in Woolsey Hall, at which Secretary Jardine spoke on "Agriculture and Modern Science." He described recent developments in chemistry, and their relation to agriculture, and the work being done in the Bureau of Chemistry, the Fixed Nitrogen Laboratory and the Bureau of Soils.

A SECOND international Conference on Bituminous Coal will be held at the Carnegie Institute of Technology in November, 1928.

ACCORDING to the *Journal* of the American Medical Association, the University of Arkansas inaugurated a weekly radio medical extension service, January 6, from Station KUOA. The first radio lecture was by Dr. Charles C. Bass, New Orleans, dean of Tulane University of Louisiana School of Medicine, on "Treatment of Malaria." Programs will be broadcast at 8 o'clock, Thursday evenings. Dr. William Engelbach was the speaker, January 13, on "Backward or

Defective Children, Physical and Mental, due to Disorders of the Ductless Glands"; Dr. Frank Smithies, Chicago, January 20, "Symptoms, Signs and Methods Available for Early Diagnosis of Alimentary Tract Cancer," and Dr. Frederick G. Banting, Toronto, Canada, January 27, "Some Aspects in the Management of Diabetes." Future lecturers in this service will be Drs. George Dock, Pasadena, Calif.; William J. Mayo, Rochester, Minn.; Francis M. Pottenger, Monrovia, Calif.; Nathaniel Allison, Boston, and Williams McKim Marriott, St. Louis.

THE second session of the Canadian School of Prehistory in France, organized by a committee of the Royal Society of Canada in 1925, is expected to open at Combe-Capelle on about June 15. Arrangements are in charge of M. Pierre Dupuy, 19 Boulevard des Capucines, Paris, and Mr. H. H. Ami, laboratory of geology and paleontology, Elgin Annex, Ottawa, Canada. The school is expected to carry on special excavations in the valley of the Touze River, Dordogne District, in the southwest of France, but will also devote some time in visiting the prehistoric sites, caves, rock shelters, etc., of the classic region about les Eyzies de Tayac.

Two different Scandinavian expeditions are planning to set out for the Kola Peninsula in the Arctic. This peninsula, about which very little is known, is joined to Finland on the west, and beyond, to the east, is Siberia. The first exploration party will leave early this summer to study the plant life of this northern region. This expedition will be directed by Dr. Bjorn Floderus, chief surgeon of the Crown Princess Louise Institute for Children in Stockholm. Dr. Floderus has conducted explorations in Greenland, northern Scandinavia and Nova Zembla and visited Kola in 1923. The second expedition is to be conducted by Fridtjof Nansen, well-known Arctic explorer. His party will not start until a year later, and will specialize in the population problems of Kola. The project has been granted aid by the Laura Spelman Rockefeller Memorial Fund, of New York.

AN anonymous gift of $100,000 for the building of the new Neurological Institute in connection with the Medical Center at 165th Street and Broadway, New York City, has been announced; the estimated cost of the institute with equipment is $1,400,000, and of this sum about $800,000 had been pledged on February 9.

THROUGH the agency of Mrs. Stanley McCormick a fund has been established to support an investigation on the relation of endocrine factors to nervous functions. The work will be carried out under the direction of Dr. R. G. Hoskins, in association with Dr. Milton O. Lee, at the Harvard Medical School and nearby psychiatric institutions.

DR. NOBLE WILEY JONES recently gave a cash gift of $5,000 to the University of Oregon School of Medicine to endow a lectureship fund, the income from which will be used to bring lecturers to Portland.

GEORGE W. EASTMAN has established three fellowships for the psychology of music under the direction of Professor C. E. Seashore in the State University of Iowa.

THERE has recently been provided at Yale University facilities for work on shade tree diseases. This was made possible by the cooperation of the U. S. Office of Forest Pathology and the botanical department of Yale University, the F. A. Bartlett Tree Expert Company furnishing financial aid. Mr. R. P. Marshall, of the U. S. Office of Forest Pathology, has been placed in charge of the work, which will be under the general supervision of Dr. Haven Metcalf, of the U. S. Department of Agriculture; Professor Evans and Dr. Clinton, of Yale University; F. A. Bartlett, of Stanford University, with Dean Graves, of the Yale Forestry School, and others in an advisory capacity.

THE department of chemistry at the University of Illinois has received an appropriation of $6,500 to be used in the construction of a laboratory for research on high pressure gas reactions. Approximately $2,500 will be spent on the building and from $4,000 to $5,000 for equipment. The reactions studied are to be those between carbon monoxide and hydrogen, with the view to producing liquid products such as motor fuels.

THE herbarium of B. B. Smyth, at the time of his death in 1913 curator of the Goss collection at Topeka, Kans., consisting of approximately 7,000 sheets, has been recently donated by Mrs. Smyth to the herbarium of Kansas State Agricultural College.

E. BRUNETTI recently presented to the department of entomology of the British Museum of Natural History a collection of some 60,000 specimens of Diptera, especially rich in Indian and North American material. The collection is the result, in part, of the entomological collecting done by Mr. Brunetti during the last forty years. The same department has also received, under the terms of the will of the late Lieutenant-Colonel F. R. Winn Sampson, a collection of insects of the group Scolytidæ (bark-beetles). The collection consists of some 11,000 insects and 1,400 microscopic preparations, and the bequest includes a selection of books and pamphlets and two microscopes.

DURING the past year the American Electroplaters' Society has been engaged in collecting from manufacturers funds to be used for cooperative researches on electroplating at the U. S. Bureau of Standards. Their goal is to obtain a fund of $10,000 per year for three years, based on contributions of $50 or more per year from each subscribing firm. To date about $4,000 per year has been raised, and the campaign is being continued by their Research Committee, of which R. J. O'Connor, Bridgeport, Conn., is chairman. W. P. Barrows, formerly of the bureau staff, has been appointed as a research associate on this fund and is starting an investigation of the causes and prevention of "spotting out" of electroplated finishes.

THE North Carolina Senate passed a bill on February 17 providing for the issuance of $2,000,000 of bonds for the purchase of land in the Great Smoky Mountains of western North Carolina for inclusion in a national park to be known as the Great Smoky National Park. The bill now goes to the House. The proposed park would lie in North Carolina and Tennessee and the two states would be required to furnish 428,000 acres of land before the U. S. Department of the Interior would take over the area for development of a park.

THE Arnold Arboretum of Harvard University has recently acquired as gifts to its library two rare volumes of unusual interest both for gardeners and horticulturists as well as for specialists in the earliest printed books. These are the first and second editions of a work called "Das Buch der Natur," by Conrad von Megenberg. The first edition of this rare volume, valued at $4,000, was the gift of J. P. Morgan, who owns the only other copy known in the United States. The second edition, also printed by Baemler at Augsburg, in 1478, was the gift of Mrs. J. M. Sears, and is the only known copy in the United States.

UNIVERSITY AND EDUCATIONAL NOTES

GIFTS aggregating $1,600,000 for additional new buildings and equipment for the Case School of Applied Science at Cleveland were announced on February 25. Charles W. Bingham, of Cleveland, gave $1,000,000; the alumni contributed $500,000. Ambrose Swasey, of Cleveland, gave $100,000 for equipment of the new mechanical laboratory.

PRESIDENT JAMES ROWLAND ANGELL has announced that pledges from 300 men totaling $6,000,000 have already been made, two months in advance of the date set for the formal opening of the $20,000,000 endowment campaign for Yale University.

PRESIDENT FRANK J. GOODNOW has announced that the Johns Hopkins University, after two years of preparation, is now in a position to operate primarily as an institution for graduate study and scientific research, with 80 per cent. of the collegiate work concentrated in the first two years of a college sharply segregated from all graduate departments. It is planned that the collegiate work, even in its curtailed and segregated form, will be continued only temporarily.

ACCORDING to press reports, the terms of the will of the late Hill S. Warwick, of New Jersey, provide that his estate of $100,000 is to go to the University of Pennsylvania upon the death or marriage of his sister. It is stipulated that the bequest be used in part for experiments upon the higher apes with a view to increasing knowledge of the cause, prevention and cure of disease.

THE Massachusetts Institute of Technology has been bequeathed the sum of $25,000 by the will of the late Russell Robb, vice-president and treasurer of Stone and Webster.

DR. EDWARD WILLIAM ALTON OCHSNER, assistant professor of surgery in the University of Wisconsin Medical School, Madison, has been appointed professor of surgery at Tulane University of Louisiana School of Medicine, New Orleans, to succeed Dr. Rudolph Matas, who is retiring from active teaching.

DR. LEE TRAVIS, for three years National Research Council Fellow in psychology and psychiatry, has been appointed assistant professor of clinical psychology and psychologist to the Psychopathic Hospital in the State University of Iowa. His work will be devoted mainly toward the direction of research within the field of speech correction.

NATIONAL Research Fellows in the Medical Sciences have received appointments as follows: Dr. Roy G. Williams, instructor in anatomy at the University of Pennsylvania; Dr. Jeffries Wyman, Jr., instructor in the department of zoology at Harvard University.

PROFESSOR C. E. HORNE, formerly dean of the College of Agriculture at Mayaguez, Porto Rico, has been appointed professor of mathematics at the University of Porto Rico.

THE title of professor of psychology in the University of London has been conferred on Dr. Beatrice Edgell, in respect of the post held by her at Bedford College.

DISCUSSION AND CORRESPONDENCE

SUMMER SCHOOL OF GEOLOGY AND NATURAL RESOURCES

DURING the past twenty years the increasing complexity of the university curriculum and the growing necessity for actual demonstration of principles,

facts and processes outside the classroom has drawn the attention of many educators to the necessity of "field trips" in connection with the regular resident courses and technical courses such as the different branches of engineering and more especially geology. While elementary and even advanced technique can best be taught in the class-room, laboratory or fixed camp, the actual demonstration of a mechanical process or natural phenomena can best be demonstrated in the "outside world," and preferably under the leadership of the man who is responsible for its success. There is nothing quite so stimulating to the conscientious student as the demonstration of a successful piece of work by the man who has helped to put it across.

In this very busy and "work-a-day" world there is an increasing necessity for showing our young men the relation of theory to practice. This statement applies as well to the cultural as to the professional studies. Further, the cultured man of to-day is expected to know a great deal more about the world that *he* lives in than was the case a quarter of a century ago, and every college boy should have some knowledge of his country's natural resources if only to make him a more conscientious citizen. The proper study of natural resources must include, not only the visualization of development of these processes, but also actual contacts with the men who have made the development possible. The principal problem has been how to conduct a "travel class" without seriously interfering with the necessary and regular work of the university, and without too great expense to the student. The Summer School of Geology and Natural Resources, with its headquarters at Princeton University, was created to solve this difficulty for American and European students and teachers. In the language of a New York newspaper, just before the trip started: "Fortunately the geologist can get among his rocks, as the astronomer would get among his stars if he could. But the geologist who stays at home is worse off than the astronomer, for the latter can at least see the moon, though he can not reach it; but the geologist can not see the great works of the earth forces without going where they have been displayed. Surely learning has not offered so pleasant an aspect since the days of Abelard and the waning scholars, who, by the way, might have been much happier and more useful if they had studied geology instead of philosophy." This statement would hold as well for history, politics, architecture and numerous other subjects, both technical and cultural.

When the work of the new school was planned it was fully realized that there would be a number of mechanical as well as educational difficulties. How could we give the class a reasonably good view of the United States in some six or seven weeks? It was soon discovered that an effective itinerary could be arranged with the American railroads and also with the men who were to form the extremely important "field faculty," but how were we to transport our party? It was not our aim to attempt to compete with the tourist agencies, but rather to afford the opportunities for travel and study to a group of individuals who needed this type of course. We quickly determined that we could not handle a party of over twenty-five men effectively in the field and that we should have to work with that unit if we wished to accomplish the best results. The first year's experiment has fully proved the strength of this conclusion and also that if the work of the school is to be extended it must be by working with units of twenty-five men, and not by taking out train loads. Now we come to the mechanical part of the problem. A special train of three or more cars, for such a small group, was too expensive. After much discussion with the officials of the Pullman Company a car was designed which should serve as the home, class-room and transportational agency for as close to twenty-five men as possible. We set the number at twenty-five in order to obtain the minimum excursion rates. Eventually we had to cut the number to twenty-three. But "the proof of the pudding is in the eating," and we did prove conclusively that we could take care of as many as twenty-three men in one car and do it comfortably. Probably this is the first time in the history of railroading that such an experiment has been successfully accomplished, and, as has already been pointed out, this type of car should prove invaluable for many purposes, especially, because of its excellent kitchen arrangement, it may be used with a standard Pullman and take care of fifty tourists. The car is of standard length (73′ – 7″ over end sills) and contains a kitchen large enough to feed fifty men; a state room and office for the two traveling instructors; six wash basins; four toilets; shower bath; library; a lecture section twelve feet long with side seats or sofas; and a regular Pullman section twelve feet long. The combined lecture and Pullman section serves both as the dining section and sleeping section. The car is also equipped with large water tanks (400 gallon capacity) heater, radio, lantern slide projector, and translux screen, roller wall maps and ample locker space. The car turned out to be a veritable land cruiser with the one exception that it does not propel itself.

Imagine the comfort of traveling in such a car as this. For instance, our land cruiser pulls into Hibbing, Minn., late in the evening and is parked on an attractive siding. Instead of having to find a hotel, the party, having dined, listens to a lecture

on the next day's excursion. At ten P. M. the berths are made up and everybody tumbles in. Next morning we breakfast in the car, put our lunches in our knapsacks, are met by our local leader or leaders. After a full day's work on the Iron Ranges we return to the car for dinner. While we are dining our car is on its way to the next locality. There is another lecture in the evening, and so the schedule continues for over 10,000 miles of railroad travel, not including side trips of 1,000 to 2,000 miles. Most of the time that we are sleeping, eating or studying we are traveling, and so we make use of every minute of the day, and accomplish as much, more comfortably and more efficiently, in one third of the time that it would take to do the same work under ordinary traveling conditions. Wherever the car can not take us we either hike, or arrange for horses or automobiles to meet us. If we wish to see some important section between stations, the railroad company (as in the case of the Northern Pacific) stops the train so that we may "go and see." Sometimes we disembark at one station and take a four days' hike across country to where our car is waiting to take care of us once again. Imagine the delight of having your home, classroom and library always with you and never having to tug a heavy suitcase and a bag of rocks around a strange town or mining camp, or wrestle with an exceedingly varied and at times somewhat unpleasant diet. To those who say that this is altogether too luxurious a mode of travel for a geologist, we would reply that by keeping the party in the best physical and mental condition we are able to get more work done.

The mechanical difficulty of transporting small classes over great distances—of taking one's students to the mountain instead of trying to bring the mountain to the students—has been solved. We have succeeded in making the great railroad system of America an integral part of the university machinery, and we believe for the benefit of both.

The excursion this summer will probably be in Canada and the itinerary will be announced not later than April 1. Those interested in joining the expedition are requested to communicate with the director of the school as early as possible.

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THE COMPOSITION OF GEOLOGICAL PUBLICATION IN THE BIENNIUM 1921–1922

THE published matter relating to geology listed in U. S. Geological Survey Bulletin 758, Bibliography of North American Geology for 1921–1922, by John M. Nickles, was analyzed by the authors in 1924 as to its sources by individuals and institutions and its composition in relation to the principal branches of geology. On completion of the study it was recognized that the two-year period was too short to indicate clearly some of the important trends and plans were laid for extending the analysis over a longer period, partly before 1921 and partly after 1922, when later bibliographic material became available. Since the completion of the extended study is remote it is thought that some of the salient facts brought out for the biennium already studied are of sufficient interest to justify presentation here.

No effort will be made to describe methods in detail; it is recognized that many errors are inherent in attempting a brief objective survey of material so varied in quality and significance as published scientific matter. The facts presented constitute an analysis of printed pages of whatever size or quality as listed in the bibliography above mentioned and for the years in question. The authors recognize clearly that the value and quality of such published matter varies enormously and moreover that no two persons would agree as to the relative value or significance of different papers. Some will feel that too much matter is being published, others that no such limit has been reached. To some of these problems the present paper contributes data without presuming at present to discuss causes, express opinions or render judgments.

The total amount of geologic matter published in the biennium 1921–1922 was almost exactly 60,000 pages, or 30,000 pages a year. Of this amount about 25,000 pages was classed as Economic Geology, about 15,000 pages as Historical Geology (including much areal geology) and the remaining 20,000 pages as Physiography, Paleontology, and Mineralogy-Petrography in the order named. The largest source of this material is the university and college group which is responsible for practically one third of the total. Another third of the total is produced by the state surveys and the U. S. Geological Survey combined, each contributing about half, and the remaining third is due to foreign, consulting, and petroleum geologists, and miscellaneous U. S. and Canadian public bureaus, museums and societies.

Relative to the total the university product is low in Economic and Historical Geology and high in the other subjects and the output of the state and national surveys shows opposite characteristics. Obviously these features are interdependent since the two groups dominate the entire production.

The total of 60,000 pages was contained in about twenty-two hundred papers written by 877 men. More than half of these men produced but one paper in the two-year period. Seven eighths of them pro-

duced four papers or less. The remaining eighth produced over 42 per cent. of the total number of papers. Of the 2,200 papers, one fifth was produced by the one-paper men, 46 per cent. by those writing three papers or less, and one fifth by those producing nine or more papers. Certain special classes, including paleontologists, mineral resource analysts, mineralogists and administrative geologists, include most of the longer individual bibliographies. Of 73 men producing over five papers, 44 belong in these classes; of 17 writing over 10 papers, 14 are so classified.

The average paper written by the one-paper men contained 34 pages; that written by the nine, ten and eleven-paper men grouped contained 17 pages. The average geologist of the entire group produced in the two-year period 2.5 papers averaging 27 pages in length, thus aggregating 34 pages per year. Twenty men in several Canadian Bureaus and Societies (excluding the Geological Survey of Canada) average 68 pages per year, 92 men in state surveys averaged 60 pages per year, 224 men in universities and colleges averaged 45 pages per year and 119 men in the U. S. Geological Survey averaged 38 pages per year.

Seventy-eight institutions appear in the university and college group. Fifty per cent. of the university total and one sixth of the entire amount was produced by men in nine leading universities. The first twenty universities were the source of over eighty per cent. of the university total. One university, Yale, during this period produced considerably over a tenth of the university total, and more than twice as much as the next university.

Among the 32 state surveys which produced a total of about 11,000 pages, the two most productive were the source of one fourth of the total and the first eight produced over 60 per cent. of the whole. It is not to be supposed that analysis of publications of another two-year period would result in identical rank of the various institutions since variations from year to year in any but the larger institutions are considerable. Nevertheless, there have been stated above only those general facts which the writers believe would be fairly characteristic of the composition of any biennium when conditions were not notably different from those during the 1921–1922 period.

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CONCERNING THE ENCYSTMENT OF BUCEPHALUS CERCARIAE

IN the October, 1926, issue of the Transactions of the American Microscopical Society, Dr. George R. La Rue makes the statement (p. 274) that the entrance of the Bucephalus larva into the second intermediate host, so far as he was aware, had not been observed. He inferred that they enter the host by penetrating through the surface of the body just as the schistosome and strigeid cercariae are known to do.

I have performed an experiment to observe the method of penetration. A small (two-inch) rock bass was placed in a finger bowl containing a fresh-water mussel (*Elliptio dilatata*) which was rapidly shedding active cercariae. As the fish fluttered about cercariae became entangled on the margin of the fins, especially the dorsal and caudal. Active movements of the fish resulted in many of the cercariae being cast off. After a few minutes the fish was transferred to a watch glass and the movements of the cercariae observed under the binocular. At first the tails of the Bucephalus aided the larva to maintain its anterior sucker in contact with the fin. Many attempts were made to find a place of entry. Gradually the tails became only a confused coiled mass, as the body portion began to penetrate. Within five minutes the body had become separated from the tails and had entered the space between the fin rays. The course of the cercariae is well defined by the bright pink color of the blood corpuscles which gather in its wake. Working by means of a worm-like movement, the cercariae, within thirty minutes of its entanglement on the fin, completes its excursion within the host and begins to encyst.

Encystment usually takes place at the base of the fin rays under the last few rows of pigmented scales. Five hours afterwards active movement was still visible within the cysts. Within twenty-four hours the characteristic clear cysts of Bucephalus are complete. These unpigmented cysts are not very visible to the unaided eye but are easily seen with a microscope. In a ten- to sixteen-inch small-mouthed bass hundreds of cysts may be found, in all the fins, but more especially on the pectorals and the caudal.

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A PROTEST

THE author has noticed an ever-increasing tendency on the part of writers of college text-books and of research papers not to conform to consistent conventions and to correct English. Accordingly, he hopes that the following concrete examples may help to ameliorate this inexcusable state of affairs.

(1) The symbol for an electric cell consists of two segments of parallel straight lines, one of which is

much shorter and thicker than the other. The thin longer line and the thick shorter line refer respectively to the copper and zinc plates which, when immersed in dilute sulphuric acid, constituted an early form of cell. The chemical actions involved made it desirable to construct the cell with a much greater mass of zinc than of copper. Hence, automatically and obviously, the longer line in the symbol pertains to the positive terminal and the shorter line to the negative one. Accordingly it should be (as it was formerly) superfluous to print plus and minus signs close to the symbol for an electric cell and it is a useless perversion of convention to reverse the polarity of the symbol. This old convention was looked into and adopted on the occasion of the writing of the second edition of "The Principles underlying Radio Communication" prepared by the U. S. Bureau of Standards for the Signal Corps, May 24, 1921. Nevertheless, in a very recent edition of a composite textbook one author marks the longer line negative and the next author labels it positive.

If the symbol for a lead storage cell consisted of an even number of lines ($2m$) to represent the grids joined to one terminal and an odd number of lines ($2m-1$) to indicate the grids of the other set, would it be at all necessary to label the terminals with plus and minus signs?

(2) By common consent the prefixes milli and micro signify respectively the one one-thousandth (10^{-3}) and the one one-millionth (10^{-6}) part of the original unit. As examples: millimeter, milliampere, . . . microfarad, microvolt, . . . Quite consistently the micron (symbol μ) is defined as 10^{-6} of a meter. Consequently the micro-micron (symbol $\mu\mu$) means (10^{-6}) (10^{-6}) meter or 10^{-12} meter, or 10^{-9} millimeter. The milli-micron (symbol $m\mu$) stands for the one one-thousandth part of a micron, that is, for the one one-millionth part of a millimeter. Such carefully edited publications as the Journal of the Optical Society of America and the Smithsonian Physical Tables use $m\mu$, but altogether too many scientists indicate the wavelength of the maximum of an absorption band in the visible spectrum as "543$\mu\mu$" or "543$^{\mu\mu}$" when 543$m\mu$ is meant. Probably this error arose from the following sequence of folly: 1μ equals 0.001 mm, hence the symbol μ denotes the multiplier 10^{-3}. Therefore $\mu\mu$ must mean (10^{-3}) (10^{-3}) mm or 10^{-6} mm. $\mu\mu$ is closer to an X-unit than to any other common unit.

(3) The singular of data is datum; nevertheless speakers and writers persist in using such combinations as "this data."

(4) The same criticism applies to the use of phenomenon and phenomena, *e.g.*, "this phenomena."

(5) It takes two or more objects to constitute a battery. One Leyden jar is not called a battery even by the confusion makers, a single boiler in a tug boat does not constitute a battery of boilers, a single field piece is not a battery in artillery practice, nevertheless a single electric cell is very frequently referred to as a battery not only in automobile service stations and in radio supplies shops but in laboratory manuals and text-books intended to guide students in the exact science called physics.

(6) The domain of Einstein's wonderful work on relativity affords, in the hands of many over-enthusiastic writers and lecturers, an almost unlimited supply of illustrations of the kind with which the present protest deals. To this extent unnecessary difficulties and hindrances are placed in the way of the general student of the subject.

H. S. UHLER

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SCIENTIFIC BOOKS

A Manual of Plant Breeding for the Tropics. By NEMESIO B. MENDIOLA. xxiii. 360 pp. Manila, University of the Philippines. 1926.

A FOREWORD by Dean Baker explains the occasion for preparing and publishing this book. "The almost total lack of texts in the many lines of modern agricultural science, especially adapted to tropical plants, to tropical crops and to tropical conditions, makes the operation of a modern college of agriculture of full university grade in any of the new tropical countries a most difficult undertaking." Such texts had to be in preparation from the day the Philippine college of agriculture opened, in 1909. The original faculty, five Americans, might prepare one or two of them; but the job as a whole had to be tackled indirectly, by training the men to write them. The college is now almost completely Filipino-manned, and Mendiola's is announced as the first of a series of texts from their pens.

The first forty pages are given to a very concise digest of the principles and methods of plant breeding in general. The comparative brevity of this general treatment indicates the scale on which more particular matters demand space.

Rice breeding follows with fifty pages. There has been a great deal of careful rice breeding, in many lands, during the last two decades, but this is the first comprehensive showing of tests of basic data. The necessity of such a comprehensive study of fundamentals is obvious from two facts: Where pure-line selection has been practiced most perfectly with rice, the result has been a colossal disappointment; and, while the publications on rice hybridization would fill a volume, not one authentic product of artificial crossing has come into farm use. The careful basic work of Mendiola and his students has yet to be applied

to the numberless varieties of rice—above two thousand in the Philippines alone. When this is done, the results will make a book by themselves.

Sugar cane follows with thirty-three pages. The concentration of private capital in sugar production has made cane one of the most perfectly bred plants, whatever the particular local objective—yield, sucrose content, purity of sap, or resistance to particular diseases. The recent boom of the Philippine sugar industry has demanded particular attention to its problems, and the results are worthy of the effort. Seven seedling strains originating at the college have come into farm use.

The subject of corn (maize) improvement receives twenty-three pages. Credited with being originally a tropical plant, maize has been bred to fit a temperate climate, until its return to the tropics is a new undertaking. Imported fine varieties, properly handled, quite regularly outyield the so-called native varieties in the dry season, but not in the wet. The immediate stimulation of yield by cross-pollination is as evident in the Philippines as elsewhere; but no hybrid has yet been established which will produce in the tropics a succession of crops nearly up to Iowa standards.

Tobacco improvement receives nineteen pages. No other crop has shown itself as dependent as this upon breeding to fit local conditions. Several places famous for their fine tobacco have undertaken in the past to prevent export of their seed, but their seed practically never produces fine tobacco elsewhere. The most of the famous tobaccos of the world have been tested at the Philippine college, and not one has proved as good there as the "native" Cagayan. However, several hybrids have been produced, with one imported parent, of which at least one is a very superior wrapper.

Coconut breeding covers twenty pages, which suffice for the first general presentation of the basic data. For example, here is the first note of a performance record of the trees of a commercial grove, indicating that only 23 per cent. of the trees are fit sources of seed. The commonly assumed uniformity of a few strains or varieties of coconut is very soundly questioned.

Abaca improvement receives only sixteen pages, enough to show how little is known about it. The guesses at the number of varieties run from fourteen to seventy. The fact is that several species are involved, some of which are without botanical names. Mendiola points out promising methods of improvement, but the most of the actual work is still to be done. And yet abaca is the most noted product of the Philippines.

Minor "crops" are covered in twenty-seven pages. These include the sweet potato, of which thirty-five native varieties have been tested at the college; cassava, perhaps the most productive crop in the world; coffee, of which the Philippines produce an excellent quality; cacao, with which they used to be credited with the finest in the world; rubber; cotton; and a number of vegetables. Briefly as these are treated, the outline of work done and needed is satisfactory for sweet potato and cassava. For rubber, it is not so, as the author is probably aware. Yams are not even mentioned.

There follow sixty-seven pages on fruit improvement, in which banana has first place. "It is probable that the largest collections of edible *Musa* are found in the Philippines," and "It is believed that many questions on hereditary phenomena may be studied and solved with this genus as material." The author proceeds to make an asset of the natural difficulty in the way of breeding this plant, outlining methods and finding room for a mass of specific data as to seedless and seedy varieties, the fertility of seed, the presence and absence of pollen, susceptibility and immunity to the wilt disease, etc. The papaya is likewise well treated. It is an especially inviting subject for the breeder, because it is commonly dioecious, and every planter wants a solid field of pistillate plants. Briefer space is given to mango, lanzon, pineapple and the citrus fruits. Dozens of other fruits are mentioned or hardly more. The virginity of this field is illustrated by the discovery on the college campus of a very savory wild fruit which turned out to represent a genus new to science.

Ornamentals close the work, with particular attention to "Croton" (*Codiaeum*) and Hibiscus.

Plant breeding in the tropics is still the work of pioneers. There are great standard crops hardly better known in a scientific sense than *Hedyachras,* the new fruit tree just mentioned, and *Leptosolena,* a wild native with real advantages over Canna for the same use. Science, as we are used to its uses in the north, is just getting established in the tropics. The breeder finds there such crops as coconut, with which breeding is a slower job than he ever found it before. He finds an ancient agriculture, in which even the formation of seed has ceased in some important crops. He finds conditions for the spread of disease more perfect than temperate conditions even suggest, and must do his work over and over, as new diseases and parasites appear. Along with the ancient agriculture, he finds a new one in its genesis, in which a plant from the forest becomes over night one of the world's great crops. Into this fascinating field Mendiola has given us a guide, so usable that it stands safely without the apology of the newness of its field.

It stands out in Mendiola's book as clearly as in this review that it is the product of an institution.

In the list of publications cited appear those of more than thirty of his Filipino colleagues and students. By such institutional activity the task depicted in Dean Baker's foreword has been carried on.

E. B. COPELAND

Emile Berliner, The Maker of the Microphone. By FREDERICK WILLIAM WILE. New York, N. Y. Bobbs Merrill Co., 1926.

FREDERICK WILLIAM WILE has been known to the American public as a newspaper correspondent and radio broadcaster, but in this book he will make himself known as the interpreter of the difficult and abstruse technical aspects of certain features of our civilization. He has done for Emile Berliner, "The Maker of the Microphone," what Michael Pupin did for himself in "From Immigrant to Inventor," and in some ways it is better.

The book is full of the romance of science, weaving as it does the conditions of the times that influenced the inventor. In particular the story of his work with the Bell Telephone Company is most readable. The story of how Bell was rewarded with success in the use of the electro-magnetic coil in making the first telephone is probably new to nearly every American. If the contact point on the coil had not welded so that it did not operate as intended, Bell might never have been known as the author of "the telephone, America's greatest invention." While Bell made use of induced electricity he did not use an "induction coil," as such is known and often termed "transformer."

Likewise Berliner by almost an accident learned that a variable contact would produce an undulating current, and from this was able to produce an undulating current corresponding to the sound pressures developed in a telephone transmitter.

The history of the telephone is fascinating, not only because of the personalities involved, but also because it shows how so many masters of many arts are involved in a great invention.

The story of the gramophone as it evolved by and about Berliner is almost as interesting as that of the telephone. The public generally does not know that the common disc record in use to-day is the invention of Berliner.

This book is commended to those who like to read a good biography, to those who like to learn how important inventions are made, and to those who like to learn once again that America is a land of opportunity.

The introduction by Herbert Hoover is a gem to be prized in any library.

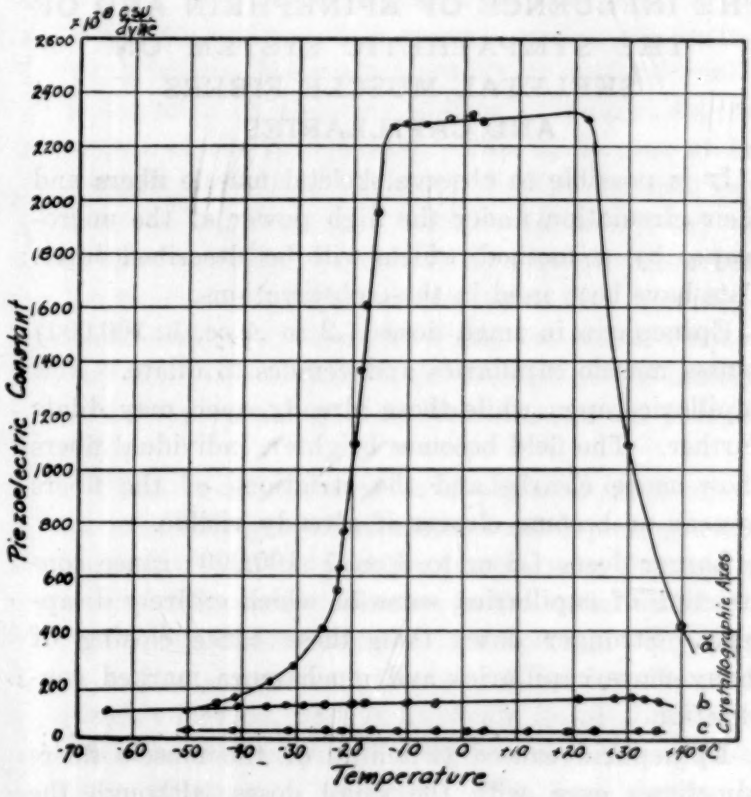
F. C. BROWN

BUREAU OF STANDARDS

SPECIAL ARTICLES

NOTE ON THE PIEZO-ELECTRIC EFFECT IN ROCHELLE SALT CRYSTALS

ALTHOUGH the piezo-electric effect in Rochelle salt crystals cut normal to the *a* crystallographic axis has been studied,[1] the only work on plates normal to the *b* and *c* axes consists of some old measurements by Pockels at room temperature. Because of the characteristic changes in piezo-electric activity at −20° C. and at 25° C. observed in plates cut normal to the *a* axis, it was thought to be of interest to obtain corresponding observations on crystal plates of other orientations. Plates were cut from a large crystal perpendicular to each of the three crystallographic axes. Electrodes of tinfoil were attached by means of Canada balsam and the pressure was applied at 45° to the axes in the plane of the faces on which the charges produced were measured. The results of these measurements are shown in Fig. 1. The charges were measured by means of an electrometer null method, except for the last three points on the curve for the *a* direction, which were obtained by



means of a ballistic galvanometer. This change was necessitated by the rapidly increasing conductivity at these temperatures.[2] The piezo-electric constants are in electrostatic units per square centimeter of electrode per unit shearing stress in dynes per square centimeter. Their values for the *a*, *b* and *c* crystallographic directions are, respectively, 2300×10^{-8},

[1] Valasek, *Phys. Rev.*, *17*, 475 (1921) and *19*, 478 (1922).

[2] Valasek, *Phys. Rev.*, *20*, 653 (1922).